STATE OF VERMONT
PUBLIC SERVICE BOARD

Docket No. 7032

Joint Petition of Vermont Electric Power Company, Inc. ("VELCO"), Green Mountain Power Corporation ("GMP") and the Town of Stowe Electric Department ("Stowe") for a Certificate of Public Good pursuant to 30 V.S.A. § 248 authorizing VELCO to upgrade a substation in Moretown, Vermont; construct .3 miles of side by side, single pole tap; construct a switching station in Duxbury, Vermont; construct 9.4 miles of 115 kV transmission line; upgrade an existing GMP 34.5 kV subtransmission line; construct a substation in Stowe, Vermont; and for Stowe to construct 1.05 miles of 34.5 kV subtransmission line in Stowe, Vermont.

SURREBUTTAL TESTIMONY OF
GEORGE E. SMITH
ON BEHALF OF THE
VERMONT DEPARTMENT OF PUBLIC SERVICE

June 27, 2005

Summary: The purpose of Mr. Smith's testimony is to respond to the prefiled rebuttal testimony of VELCO witness Ryan Johnson regarding the issues of appropriate transmission structure configurations, the resultant reliability of these configurations, and the impacts of these configurations on structure heights.

# Surrebuttal Testimony
# of
# George E. Smith

**Identification of Witness and Qualifications**

Q. Please state your name.

A. My name is George E. Smith and I am a professional engineer licensed by the State of Vermont.

Q. Are you the same George E. Smith that prefiled testimony in this case on behalf of the Vermont Department of Public Service on April 11, 2005?

A. Yes, I am.

**Overview**

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to respond to the prefiled rebuttal testimony of VELCO witness Ryan Johnson regarding the issues of appropriate transmission structure configurations, the resultant reliability of these configurations, and the impacts of these configurations on structure heights.

**Recommended Structure Type and Reliability Impact**

Q. In your prefiled direct testimony in this case, at pages 18 through 20, you discuss available techniques for lowering the height of the proposed transmission structures. Among the techniques you discuss is the use of braced post insulators. The prefiled rebuttal testimony of VELCO witness Ryan Johnson addresses the issue of shorter transmission structures within the context of so-called "hot line" maintenance. Given Mr. Johnson's testimony on this issue, has you thinking changed regarding the type of single pole, double circuit structure that would be appropriate for the proposed Lamoille project?

A. Yes. As a result of gaining a better understanding of VELCO's "hot line" maintenance practices and techniques,[1] I now believe that the use of a single pole, double circuit braced post insulator configuration would not be appropriate for the proposed transmission project. Use of braced post insulators would not allow VELCO to perform "hot line" maintenance, i.e., perform certain maintenance functions on one circuit while keeping the other circuit in service.

Q. Is there a single pole, double circuit configuration that you believe would be appropriate for use in the proposed project, one that would allow for "hot line" maintenance?

A. Yes. A single pole, double circuit configuration using davit arms would permit VELCO to perform the necessary maintenance with either or both circuits energized. This structure type is presently used by VELCO on its Williston to Queen City line where a VELCO 115 kV line is co-located with a Green Mountain Power Corporation 34.5 kV line. (See VELCO's Response 11 to the Department's Eleventh Set of Information Requests which is attached to this testimony as Exhibit DPS-GES-11.) A drawing illustrating this type of structure is provided as Exhibit DPS-GES-12.[2]

Q. In the prefiled rebuttal testimony of VELCO witness Ryan Johnson at page 2, he discusses the reliability advantages of having the 115 kV and 34.5 kV lines on *separate* structures. Do you still believe that placing both the 115 kV and 34.5 kV circuits on a single pole, using davit arms, can provide appropriate reliability for the proposed Lamoille project?

A. Yes.

---

[1]See VELCO's Responses 2 through 11 to the Department's Eleventh Set of Information Requests which are attached to this testimony as Exhibit DPS-GES-2 through Exhibit DPS-GES-11.

[2]The drawing attached as Exhibit DPS-GES-12 is intended only as an illustration of a single pole, double circuit davit arm structure type. As discussed below, a single shield wire rather than the double shield wire shown on this drawing would provide adequate lightning protection. Also, the pole can be constructed of wood, rather than steel, and be directly embedded into the ground.

Q. Please explain.

A. First, I note that Department witness David Raphael recommends the use of single pole, double circuit structures for only 3.1 miles of the proposed 9.4 mile project. Hence, exposure to a double circuit failure is limited. Also, in the improbable event of a permanent double circuit failure, say due to a catastrophic structure failure or multiple line failure resulting from a large tree falling, this would result in a substantially less severe contingency than the worst contingencies that could impact the existing system.

Q. Please explain how the double circuit loss referenced above is less severe than the worst contingencies that could impact the existing configuration.

A. First, by comparing the one-line diagrams provided in the prefiled direct testimony of VELCO witness Kim Moulton,[3] the double circuit loss impact can be compared to a contingency case simulated by Ms. Moulton for the existing system, namely the opening of the 3313 breaker at Little River. The contingency results (refer to Exhibit KSM-2, page 10, Table 4) indicate that post contingency low voltages occur for 2001 load levels and that non-convergence[4] occurs for 2002 load levels of approximately 72 MW. For this contingency, (refer to Exhibit KSM-2, Appendix 7, Existing 2003) the Mountain line plus Dewey Hill substation loads totaling approximately 15 MW will remain tied to the remainder of the loop fed from the north via Morrisville. Note however, as can be observed from Exhibit KSM-2, page 6, Table 1 and Exhibit KSM-2, page 10, Table 4, this contingency is much less severe than one of the major contingencies, such as the opening of the 3312 breaker at Middlesex. This 3312 contingency is much more severe than the 3313 open breaker contingency due to the fact that in addition to the Mountain Line plus Dewey Hill loads, the Waterbury loads are also

---

[3]See Exhibit KSM-2, Appendix 1, the one-line diagram labeled KSM-021; and Exhibit KSM-2, Appendix 6, the one-line diagram labeled KSM-023.

[4]Non-convergence, as experienced by a load flow simulation of a relatively weak transmission network such as that serving the Lamoille area, is an indication that voltage collapse is likely to occur in the event of a contingency. This collapse can cause outages over a sizeable portion of the local area.

tied to the single feed from the north. For this severe case, non-convergence occurs at approximately 50 MW of load.

Now, consider the case of the improbable double circuit outage between Little River and the proposed Stowe substation (refer to Exhibit KSM-2, Appendix 6, the one-line diagram labeled KSM-023). Upon the contingency, the 3313 breaker at Little River plus all four breakers in the Stowe ring bus will open to clear the faults on the two circuits. This will cause the 15 MW Mountain line plus Dewey Hill substation load to be shed thereby unburdening the 34.5 kV loop feed from the north via Morrisville. The result is that it is unlikely that other loads in the local area will be lost. Depending on the load levels and other factors, including the nature and location of the outage, some or all of the lost load can be restored by post contingency switching procedures.

Q. In Mr. Johnson's prefiled rebuttal testimony at page 2, he states that having both circuits on the same structure will increase the possibility of losing both circuits due to a danger tree falling. Do you believe that the petitioners' proposal, in which two separate structures are placed in a 100 ft right-of-way, is immune to this type of double circuit failure?

A. No. The petitioner's configuration places the centerline of the 34.5 kV circuit 25 ft from the edge of the right-of-way. Therefore, a large danger tree falling from this side could conceivably cause a catastrophic failure of both circuits. One might characterize the petitioner's configuration to be roughly half as prone to this mode of catastrophic failure as the single pole, double circuit configuration.

Q. In Mr. Johnson's prefiled rebuttal testimony at page 2, he states that if both circuits are on the same structure and there was a catastrophic failure of the structure, both circuits would be lost. Further, at page 3, Mr. Johnson recommends that if a single pole, double circuit configuration is to be used, that the poles should be constructed of steel rather than wood, and that the structures should have concrete foundations rather than be directly embedded into the ground. Do you share Mr. Johnson's concerns with possible catastrophic structural failures and the need for structures to be made of steel poles with concrete foundations?

A. No. While minimizing the risk of structural failures and using steel poles with concrete foundations may be required for some bulk transmission applications, I don't believe that the incremental costs, estimated by VELCO to be an additional $900,000 per mile, would be justified for the proposed project.

Q. What is the basis for your conclusion?

A. I base this on several factors including the impact of the event, the likelihood of the event occurring, and VELCO's experience with embedded wood pole structures. With regard to the impact of the event, should such an improbable double circuit outage occur, due to appropriate actions of the protective relay systems, the outage will be contained in the local area and therefore will not adversely impact the security of VELCO's bulk system and other connected customers. In addition, due to the location in the network as described above, load levels would have to be extremely high in order to cause even a local area outage. Second, I believe that the double circuit catastrophic failure mode event has a low probability of occurring due to the limited exposure (3.1 miles or less), VELCO's intention to perform adequate precautions with regard to danger trees that pose a potential threat to the line, and the relatively low likelihood of extremely severe weather events that could impose stresses beyond the design capability of the line. Third, I have reviewed VELCO's outage data base that was provided in Response 14 to the Department's Eleventh Set of Information Requests, attached as Exhibit DPS-GES-13, and observe that the only structure failures experienced over the last 20 years have been cross arm failures. There have been no failures of embedded poles on the VELCO system. This is based on the experience with some 400 miles of 115 kV transmission lines. Granted, this is based on VELCO's experience with H-frame structures which in some ways are more robust than single pole structures, but it does point to the fact that properly installed and maintained embedded poles, given their past history of exposure to extreme weather events, including the ice storm of 1998, can provide reliable performance. I also note that VELCO is in the process of using embedded wood structures for its construction of the Irasburg to Mosher's tap single pole, double circuit line.

Q. Does VELCO provide a quantitative analysis of the expected reliability of steel poles with concrete foundations versus the reliability of directly embedded wood poles to support its recommendations?

A. No. In Petitioners' Response 21 to the Department's Eleventh Set of Information Requests, attached to this testimony as Exhibit DPS-GES-14, VELCO provides only qualitative justification for the incremental expenditure of $900,000 per mile for steel structures with concrete foundations. Given the impact of a double circuit outage, the likelihood of the event occurring, and VELCO's experience with embedded wood pole structures, I believe that this level of incremental expenditure cannot be justified. Also, this mode of construction may require use of larger construction equipment creating the potential for adverse environmental impact to the ROW during construction.

**Impact on Structure Height**

Q. Will the single pole, double circuit structures with davit arms that you recommend be taller than the 115 kV single pole, single circuit davit structures proposed by the petitioners?

A. Yes.

Q. How much taller do you estimate them to be?

A. The use of double circuits on a single pole requires that three of the phase conductors, instead of two, be placed on one side of the structure. Using the spacing scaled from the structures used for the Queen City line (refer to Exhibit DPS-GES-12), this would add approximately 13 ft to the height of the structures. (Note that VELCO uses a vertical spacing of 15 ft, rather than 13 ft, for their proposed single pole, single circuit 115 kV structures.)

Q. Can the heights of the single pole, double circuit davit structures be mitigated by the same measures that you suggested in your prefiled direct testimony on pages 18 through 20?

A. With the exception of the use of braced post insulators, yes. Reducing the height of the shield wire above the topmost conductor provides a 4.5 ft reduction. Reducing the vertical spacing between two of the conductors from 15 ft to 13 ft affords an additional 2 ft. (The increase assumed above by adding the third conductor already assumes a spacing of 13 ft between conductors, so only one 2 ft savings can be achieved.) Therefore, the net pole height increase above that of the petitioners' proposed 115 kV structure by going to a single pole, double circuit davit configuration is 6.5 ft. I also note that neither of these measures significantly affects the potential for vegetation contact as these measures do not impact the height of the bottom conductor.

Q. In his rebuttal testimony at page 4, Mr. Johnson comments on the shield angle calculations at pages 18 and 19 of your prefiled direct testimony. In VELCO's Responses 27 and 36 to the Department's Eleventh Set of Information Requests, which are attached to this testimony as Exhibit DPS-GES-15 and Exhibit DPS-GES-16 respectively, Mr. Johnson further comments on this subject. Based on these comments, do you have anything to add to help clarify this issue?

A. Yes. First, it is apparent that Mr. Johnson and I used different definitions of angle in our statements and that this has been the source of some confusion. Accepting Mr. Johnson's definition of the angle as being measured from the vertical plane of the shield wire to the top conductor, with the shield wire at the apex, we agree that the shield angle of the configuration as proposed by VELCO is approximately 30 degrees. Reducing the height of the top portion of the pole (lowering the shield wire) by 4.5 ft, increases this angle to approximately 45 degrees.

Q. Doesn't increasing the shield angle to 45 degrees result in reduced lightning protection?

A. Not necessarily. It is important to note that reducing the pole height also reduces the surge impedance of the ground wire which in turn can enhance the lightning protection. I note that in Response 38 to the Department's Eleventh Set of Information Requests, which is attached as Exhibit DPS-GES-17 ,VELCO has not performed any analysis to substantiate its reliability concerns with a shield angle greater than 30 degrees. Perhaps more importantly, and as I stated in my prefiled direct testimony (page 18, line 20 through page 19, line 6), most of VELCO's 115 kV structures in the field today employ shield angles of 45 degrees. And finally, I note that the majority of lightning incidents involving shield failures result in a momentary interruption to the circuit lasting only a second or two, and as such do not pose significant threats to reliability.

Q. In his rebuttal testimony at page 3, Mr. Johnson expresses VELCO's concerns with reducing pole height by reducing span length. In Response 24 to the Department's Eleventh Set of Information Requests, which is attached as Exhibit DPS-GES-18, Mr. Johnson acknowledges that reducing the span length does not lower the conductor at mid-span, and in Response 25 to the Department's Eleventh Set of Information Requests, which is attached as Exhibit DPS-GES-19, VELCO employee Mr. Wright states that any reduction in conductor height has a direct effect on vegetation height that can be tolerated *inside* of the right-of-way. How does this impact your recommendation of using reduced span length to achieve reduced pole heights?

A. I understand VELCO's concerns and believe that they should be given due consideration with regard to this aesthetic mitigation option. I note that the concerns do not apply at mid span, but increase very slightly at first, then to a higher degree as one approaches the structures. As I stated in my prefiled testimony, a substantial portion of the proposed construction already uses spans on the order of 300 ft, so application of this option would in fact be limited. Also, there may be other factors governing placement of the poles that may rule out this option in some areas. I recommend that the decision to use this option to achieve pole height reduction be made on a structure-by-structure basis in the context of the potential for aesthetic enhancement, the local terrain, surrounding vegetation, and other relevant factors.

Q. Does this conclude your prefiled surrebuttal testimony.

A. Yes.

<u>Requests Relating to Prefiled Rebuttal Testimony of Ryan C. Johnson</u>

2. Refer to Ryan Johnson's Rebuttal Testimony at p. 2, A3. In Mr. Johnson's response, does he assume that the workers are climbing the poles in order to perform "hot" line maintenance?

Yes.

Response provided by Jeff Wright.

3. Refer to Ryan Johnson's Rebuttal Testimony at p. 2, A3. For those structure configurations that do not lend themselves to "hot" line maintenance using VELCO's pole climbing techniques, does VELCO presently have the means to employ "hot" line maintenance other than pole climbing? For example, do VELCO employees have the equipment and training to work from a bucket to perform line maintenance?

No.

Response provided by Jeff Wright.

4. If VELCO does not presently have the means described above, please provide an estimate of the cost of acquiring the necessary equipment to perform "hot" line maintenance along the Lamoille 115 kV ROW. Please briefly describe the type of equipment that VELCO would propose and list the advantages and disadvantages of its use.

The prices range from $500,000 to $750,000 for the unit. A tractor and trailer to haul the unit would cost another $150,000.

VELCO has researched the logistics of a track mounted bucket truck that we could use for energized line work on the VETCO 450 kV DC line and on vertical construction lines like the Derby to Richford and Mosher's Tap to Irasburg lines. We determined that fully utilizing a unit like this would add an unnecessary layer of complexity to performing the work. The transportation requirements would mean added resources and cost, the maintenance on a vehicle like this is very stringent, costly and in some cases the damage to the ground would be unacceptable to landowners, meaning expensive ground repairs. These were the primary reasons that we decided against changing our work methods and to continue climbing the poles.

Response provided by Jeff Wright.

5. Do other means of hot line maintenance such as working from buckets involve the same clearance issues as pole climbing techniques? Please explain.

OSHA Standard 1910.269 addresses all live line work and the same minimum approach distances apply to line workers working from a bucket truck as those working from the pole.

Response provided by Jeff Wright.

6. For VELCO's proposed davit arm structures, how does a reduction in vertical spacing of davits, while keeping davits the same length, reduce working clearances or otherwise complicate VELCO's "hot" line procedures?

The first step in performing an insulator or davit arm change out is to grasp the conductor with hot sticks and the necessary rigging. After the conductor is gripped adequately, the conductor is disconnected from the insulator allowing the conductor to be dropped to a safe distance away from the component that needs replacement. Reducing the vertical space results in reducing the distance that the conductor can be dropped.

Response provided by Jeff Wright.

7. Please provide the applicable clearance requirements, for "hot" line work, related to worker safety and identify the source (NESC, OSHA or other).

The applicable safety standards that state the necessary minimum approach distance requirements for live line maintenance is located in OSHA 1910.269 Table R6. Table R6 does not take into account the variables that a line worker encounters while performing live line maintenance such as worker size, workspace, ergonomic movement and the type of work to be performed.

Table R-6. - AC Live-Line Work Minimum Approach Distance

| Nominal voltage in kilovolts phase to phase | Distance | | | |
|---|---|---|---|---|
| | Phase to ground exposure | | Phase to phase exposure | |
| | (ft-in) | (m) | (ft-in) | (m) |
| 0.05 to 1.0 | (4) | (4) | (4) | (4) |
| 1.1 to 15.0 | 2-1 | 0.64 | 2-2 | 0.66 |
| 15.1 to 36.0 | 2-4 | 0.72 | 2-7 | 0.77 |
| 36.1 to 46.0 | 2-7 | 0.77 | 2-10 | 0.85 |
| 46.1 to 72.5 | 3-0 | 0.90 | 3-6 | 1.05 |
| 72.6 to 121 | 3-2 | 0.95 | 4-3 | 1.29 |
| 138 to 145 | 3-7 | 1.09 | 4-11 | 1.50 |
| 161 to 169 | 4-0 | 1.22 | 5-8 | 1.71 |
| 230 to 242 | 5-3 | 1.59 | 7-6 | 2.27 |
| 345 to 362 | 8-6 | 2.59 | 12-6 | 3.80 |
| 500 to 550 | 11-3 | 3.42 | 18-1 | 5.50 |
| 765 to 800 | 14-11 | 4.53 | 26-0 | 7.91 |

Footnote(4) Avoid contact.

Response provided by Jeff Wright.

8. For the proposed 115 kV line, please briefly describe all expected maintenance activities required (such as insulator replacement, hardware repair and adjustment) and provide the expected average frequency of each in terms of number of structures per year for the Lamoille 115 kV line.

The most common maintenance activity on any power line is the tightening of hardware and the repair of ground & static conductors and connections. These items are found mostly during a comprehensive aerial inspection, which is done on a ten year interval. It has been our experience that repairing the items found during these comprehensive inspections typically requires us to climb and work on approximately one-third of the structures, with increased problems found as the line ages.

In addition to these problems, we often find vandalized broken insulators, flashed insulators from lightning strikes, conductors that have been shot by vandals and other emergency problems. These are typically discovered during one of our routine patrols, which are done four times per year.

Response provided by Jeff Wright.

9. For a single pole, double circuit configuration using braced post insulators, such as VELCO is using for the line from Irasburg to Moshers tap, please briefly describe why both circuits need to be de-energized in order to perform routine maintenance on the 115 kV circuit. Would the equipment identified in response to Q4 above, if acquired, permit "hot" line work to be done with one or both circuits energized?

The minimum approach distances prevent line workers from safely climbing the pole while either circuit is energized. Utilization of an aerial lift could allow for some maintenance activities to be performed, which would be limited to working on the conductor attachment to the insulator. Each case would have to be evaluated prior to choosing the work method.

Response provided by Jeff Wright.

10. For the Northern Loop project as proposed, for the portion from Irasburg to Moshers tap, or any other portion using construction similar to that from Irasburg to Moshers tap, does VELCO plan to remove portions of the 115 kV northern loop from service to perform maintenance on the 48kV circuit of VEC? Please explain.

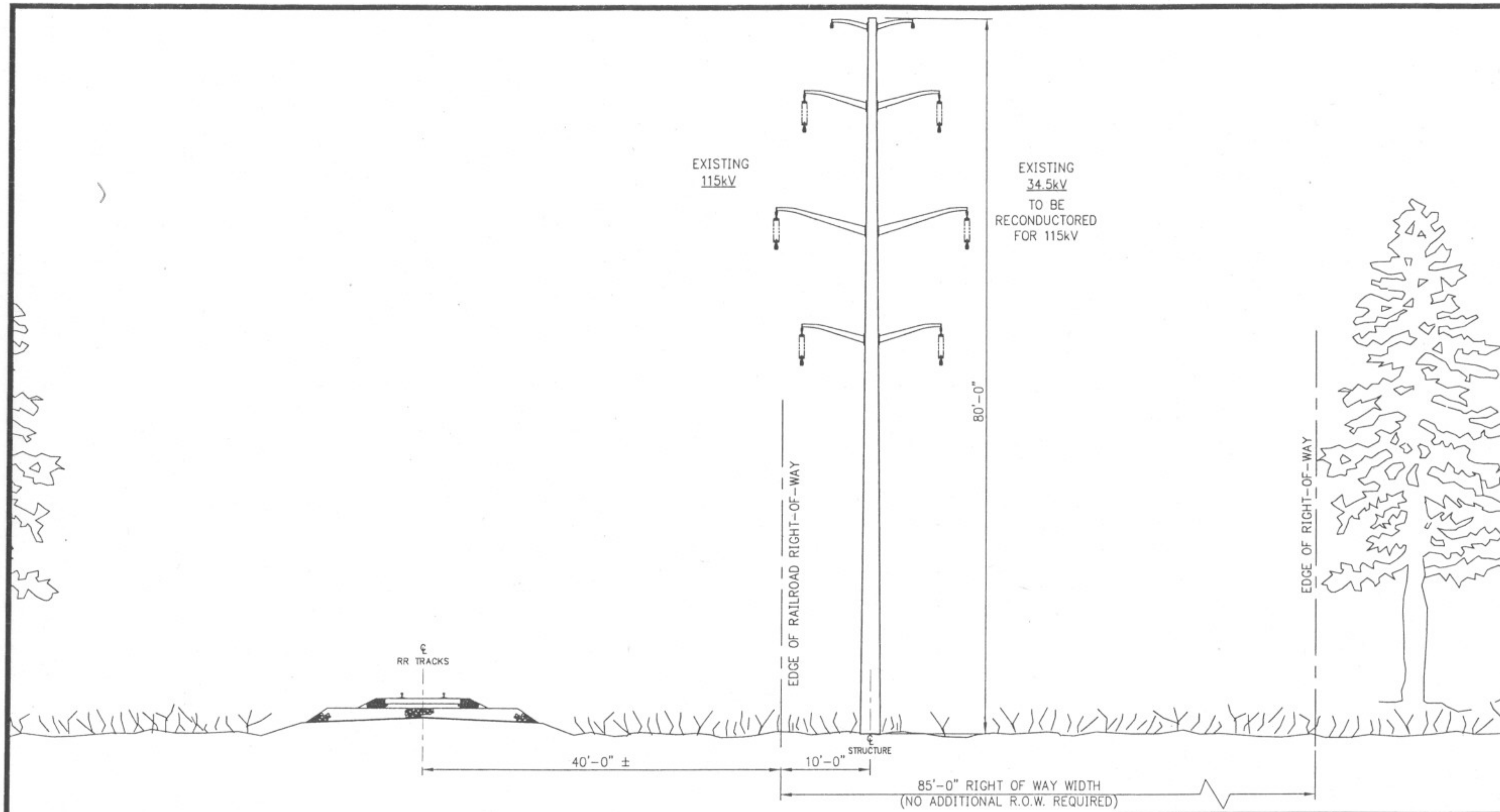
VELCO plans to take the line out of service (both circuits) for all maintenance activities that require the line worker to climb the pole. In the case of the Irasburg to Mosher's Tap line, we can readily take the line out of service for maintenance because it is a loop feed. The proposed line to Stowe, however, is a radial feed that will be heavily relied upon and difficult to remove from service.

Response provided by Jeff Wright.

11. Consider VELCO's 115 kV/ 34.5 kV single pole, double circuit configuration used for the circuit supplying VELCO's Queen City substation. Using VELCO's pole climbing techniques, could both circuits remain energized while performing maintenance on the 115 kV circuit? If not, would the 34.5 kV circuit need to be de-energized to perform "hot" line maintenance on the 115 kV circuit? Please explain.

VELCO is able to perform maintenance activities on either circuit with the other circuit energized.

Response provided by Jeff Wright.




LOOKING NORTH
VERGENNES SUBSTATION TO QUEEN CITY SUBSTATION
IN THE TOWN OF SOUTH BURLINGTON
MILE 25.44 TO MILE 26.07

**Docket No. 7032**
**George E. Smith, Witness**
**Exhibit DPS-GES-12**
**Page 1 of 1**

| REV | DATE | DR | CK | DESCRIPTION |
| --- | --- | --- | --- | --- |

VELCO — VERMONT ELECTRIC POWER CO., INC.
RUTLAND, VERMONT

NEW HAVEN – QUEEN CITY
115kV LINE
TYPICAL CROSS SECTION
DOUBLE CIRCUIT STEEL

| | | | |
| --- | --- | --- | --- |
| SCALE: NONE | DRAWN BY: DDL | APPROVED BY: | |
| DATE: 01-14-03 | CHECKED BY: MJM | | DATE |
| DRAWING NUMBER: PLOT: 1:1 | CROSS SECTION 22 | | 0 REV. |

13



14. Please describe each incident over the past twenty years of catastrophic structure failures experienced by VELCO.

See attached DPS11-VELCO-14 showing VELCO's Operation Department's list of all equipment- related outages on its system since 1986.

Response provided by Kim Moulton.

ir-perm-equip.xls

| report | report_no | date | time | title | duration | fault_type | analy_by | analy_date |
|---|---|---|---|---|---|---|---|---|
| 01-1987 | 1987-001 | 1/17/1987 | 15:16 | Essex K25 breaker: Operated due to a failed 115KV L/A on the E. Avenue 115/13.8KV transformer. | 6.11 | | | - - |
| 01-1991 | 1991-001 | 1/8/1991 | 23:13 | Middlebury 230-3 and VB72 C/S's: Operated due to defective 115KV fuses on the VB72 cap bank. | 1.86 | | | - - |
| 02-1987 | 1987-002 | 2/9/1987 | 07:26 | New Haven H74 breaker: Operated due to equipment failure. | 4.40 | | | - - |
| 02-1988 | 1988-002 | 1/18/1988 | 15:40 | E. Fairfax X19 breaker: Operated due to insulator failure at VEC's Cambridge #3 substation. | .000 | | | - - |
| 02-1991 | 1991-002 | 1/13/1991 | 02:58 | Middlebury H72, W. Rutland K30, Florence H84,B10,B11,B12 breakers: Operated due to a defective VB72 interrupt | .716 | | | - - |
| 02-1994 | 1994-002 | 1/22/1994 | 11:59 | Highgate H60, H10, H11 and Converter S.B1 breakers: Operated due to a broken insulator at Highgate sub. | .066 | | | - - |
| 03-1987 | 1987-003 | 2/22/1987 | 14:41 | Essex X62 and X66 breakers: Operated due to a failed insulator on the 34.5KV bus PT fuse holder. | 4.15 | | | - - |
| 03-1988 | 1988-003 | 1/19/1988 | 15:33 | Hartford H83 breaker: Operated due to a failed but insulator in CVPS' 46KV system. | .000 | | | - - |
| 04-1990 | 1990-004 | 3/10/1990 | 11:30 | E. Fairfax X29 breaker: Operated due to a failed insulator in VEC's 46KV system. | .800 | | | - - |
| 04-1991 | 1991-004 | 2/14/1991 | 17:42 | Bennington Y25 Breaker: Operated when a sleeve pulled apart on NEPCO's portion of the Y25 line. | .400 | | | - - |
| 04-1993 | 1993-004 | 2/7/1993 | 23:30 | Vermont Yankee K186 breaker: Operated when a 46KV-69KV fault cause CVPS' 115/46KV transformer to fail. | .000 | | | - - |
| 04-1994 | 1994-004 | 2/3/1994 | 15:24 | Converter S.B1 and N.B1 breakers: Operated when HQ's power source to Bedford was interrupted. | .700 | | | - - |
| 05-1987 | 1987-005 | 3/22/1987 | 20:01 | Essex X62 and X66 breakers: Operated due to a failed PT at GMP's 34.5KV Essex substation. | 18.8 | | | - - |
| 05-1991 | 1991-005 | 2/16/1991 | 05:22 | Bennington K4, K6, H37 and Y73 Breakers: Operated on Transformer Differential due to a Failed Insulator. | 8.95 | | | - - |
| 06-1986 | 1986-006 | 2/21/1986 | 18:42 | Blissville H30 breaker: Operated due to a line fault in CVPS's 46KV system. | 27.8 | | | - - |
| 06-1987 | 1987-006 | 3/25/1987 | 17:05 | Bennington Y73 breaker: Operated due to an insulator failure on the 259 disconnect. | 6.81 | | | - - |
| 06-1989 | 1989-006 | 3/24/1989 | 12:52 | E. Fairfax X29 breaker: Operated due to failed insulator on VEC's #3 Cambridge tap. | .816 | | | - - |
| 08-1986 | 1986-008 | 3/11/1986 | 03:20 | E. Fairfax X29, Irasburg H39 and h15 breakers: Operated due to an insulator failure on the 34.5kV at VEC #3 ta | 9.15 | | | - - |
| 08-1987 | 1987-008 | 3/24/1987 | 01:23 | Florence B10 breaker: Operated due to a phase down in VMCO's 46KV system. | 6.46 | | | - - |
| 08-1989 | 1989-008 | 3/29/1989 | 20:28 | Irasburg H15 breaker: Operated due to transformer trouble in CU's system at Barton. | 2.03 | | | - - |
| 08-1991 | 1991-008 | 3/6/1991 | 13:00 | Cold River H32 breaker: Operated when a line sleeve and two insulators failed on CVPS' 44KV line. | .850 | | | - - |
| 09-1991 | 1991-009 | 3/13/1991 | 22:27 | Vermont Yankee 81-1T,379,79-40 and 1T breakers: Operated due to a fault caused by broken 345KV insulators. | 120. | | | - - |
| 10-1991 | 1991-010 | 3/19/1991 | 09:40 | Highgate H12 breaker: Operated when an underground terminal in SVE's 7.5KV system. | .500 | | | - - |
| 10-1993 | 1993-010 | 4/23/1993 | 05:58 | Hartford H83 and Windsor H21 breakers: Operated when an insulator failed on CVPS's 46KV bus at Taftsville. | .000 | | | - - |
| 13-1993 | 1993-013 | 4/28/1993 | 10:56 | New Haven H74 breaker: Operated when an L/A failed resulting in a 34.5KV to 12KV fault in GMP's system. | .000 | | | - - |
| 16-1989 | 1989-016 | 5/21/1989 | 14:19 | Bennington K4, K6, H37, Y73 breakers: Operated when an L/A failed on the 46KV side of the 115/46KV trans. | 3.83 | | | - - |
| 16-1990 | 1990-016 | 5/27/1990 | 03:46 | Queen City X69 and B43 breakers: Operated due to damage caused by a failed PT at GMP's Moran #23 substation. | .000 | | | - - |
| 16-1992 | 1992-016 | 5/14/1992 | 11:00 | Ascutney K149 breaker: Operated due to a broken crossarm between Ascutney Tap and Bellows Falls. | 1.83 | | | - - |
| 17-1991 | 1991-017 | 4/23/1991 | 15:47 | Bennington Y25 breaker: Operated due to failed L/A's at GMP's Dover substation. | .616 | | | - - |
| 18-1986 | 1986-018 | 5/20/1986 | 17:51 | Converter N.B1 and S.B1 breakers: Operated due to stuck 50N relay contacts on HQ's Bedford 120-3 breaker. | 3.40 | | | - - |
| 18-1992 | 1992-018 | 5/30/1992 | 17:27 | Middlebury K30 and H72, Florence H84,B10,B11,B12 breakers: Operated due to failed L/A on Middlebury transform | 6.28 | | | - - |
| 19-1986 | 1986-019 | 5/29/1986 | 18:39 | Highgate H10 breaker: Operated due to a downed static wire on CU's 48KV line. | 2.55 | | | - - |
| 20-1988 | 1988-020 | 5/31/1988 | 09:47 | Queen City X69 breaker: Opened by SCADA, resulting in GMP's Queen City breakers to open due to a shorted diod | .066 | | | - - |
| 21-1991 | 1991-021 | 5/8/1991 | 12:37 | Vermont Yankee K186 breaker: Operated when CVPS' 153 C/S at Vernon Rd. substation failed. | 26.5 | | | - - |
| 23-1988 | 1988-023 | 6/9/1988 | 08:00 | Hartford H83 breaker: Operated due to a failed tertiary L/A on the 115/45KV transformer. | 6.86 | | | - - |
| 24-1988 | 1988-024 | 6/9/1988 | 12:49 | IBM 1592 breaker: Operated due to an out of adjustment interlock contact on the 5911 airbreak. | .050 | | | - - |
| 24-1992 | 1992-024 | 8/24/1992 | 11:46 | Florence H84,B10,B11,B12 and Blissville H30 breakers: Operated due to blown line pot CVPS's B-7. | .866 | | | - - |
| 28-1991 | 1991-028 | 6/15/1991 | 22:22 | Vermont Yankee 31-1T, 379, 79-40, 381 and 1% breakers: Operated due to a fault on the 381 line. | 24.0 | | | - - |
| 31-1991 | 1991-031 | 8/3/1991 | 13:20 | E. Fairfax X29 breaker: Operated due to failed insulators at the Village of Hyde Park's substation. | 1.91 | | | - - |
| 32-1990 | 1990-032 | 7/10/1990 | 09:54 | Middlesex X65 breaker: Operated due to a failed CT at GMP's Middlesex substation. | 4.45 | | | - - |
| 33-1992 | 1992-033 | 9/30/1992 | 22:14 | Essex K21,K22,K23,K24,K25,X62,X66, Georgia K21, E. Avenue B64 breakers: Operated due to Bus Differential. | 1.96 | | | - - |
| 35-1988 | 1988-035 | 6/25/1988 | 20:46 | Irasburg H16 breaker: Operated due to a failed L/A in CU's 48KV system. | .150 | | | - - |
| 37-1989 | 1989-037 | 7/14/1989 | 06:08 | Converter N.B1 and S.B1 breakers: Operated on bus differential due to failure of phase C of S.B1.1 breaker. | 1.51 | | | - - |
| 38-1992 | 1992-038 | 12/5/1992 | 04:58 | Hartford H83 and Windsor H21 breakers: Operated when a grounding transformer failed at CVPS' Taftsvill sub. | .983 | | | - - |
| 40-1989 | 1989-040 | 7/27/1989 | 05:46 | Ascutney K149 breaker: Operated due to NEPCO's failed 340 switch at Bellows Falls. | .150 | | | - - |
| 41-1990 | 1990-041 | 8/7/1990 | 10:34 | Coolidge KT1 and K31 breakers: Operated when the KT1-32 breaker failure relay operated incorrectly. | 3.50 | | | - - |
| 41-1991 | 1991-041 | 9/19/1991 | 22:47 | Sand Bar K22, Essex K22 and X66 breakers: Operated when a splice failed on the 115KV line. | 16.0 | | | - - |
| 42-1991 | 1991-042 | 9/21/1991 | 11:58 | Cold River H33 breaker: Operated when a line PT failed at CVPS' Cavendish substation. | .616 | | | - - |
| 47-1993 | 1993-047 | 8/1/1993 | 00:28 | Essex and Sand Bar K22 breakers: Operated when a T-connector failed on the 115KV line. | 6.41 | | | - - |
| 48-1988 | 1988-048 | 8/10/1988 | 14:43 | Ascutney K174 breaker: Operated due to a broken crossarm on PSNH's M127 line. | .466 | | | - - |
| 49-1995 | 1995-049 | 8/22/1995 | 07:47 | Barre X04 breaker: Operated due to insulator failure in GMP's 34.5KV system. | .136 | | | - - |
| 50-1991 | 1991-050 | 12/26/1991 | 13:54 | E. Fairfax X19 breaker: Operated due to a failed insulator at VEC's #4 Underhill substation. | 1.01 | | | - - |
| 56-1988 | 1988-056 | 9/30/1988 | 07:42 | IJ60 Line: Granite K51 and K53, Irasburh H39, St. Johnsbury X14 and X22 breakers: Operated due to a fault at | .250 | | | - - |
| 58-1989 | 1989-058 | 9/22/1989 | 04:06 | Vermont Yankee 81-1T and 381 breakers: Operated during a large load swing due to a relay set too light. | 2.08 | | | - - |
| 60-1987 | 1987-060 | 10/17/1987 | 12:51 | K21 Line (Essex and Georgia): Operated due to a trip relay malfunction. | .350 | | | - - |
| 62-1986 | 1986-062 | 7/26/1986 | 16:20 | Florence H84, B10, B11, B12 breakers: Operated due to a failed bushing CT in the 115/46KV transformer. | 53.7 | | | - - |
| 62-1989 | 1989-062 | 9/23/1989 | 02:03 | Vermont Yankee 381 and 81-1T breakers: Operated during hurricane Hugo due to a 381 line primary relaying prob | 1.53 | | | - - |
| 62-1995 | 1995-062 | 11/16/1995 | 11:54 | Bennington Y25 breaker: Operated due to a burnt off phase on the Searsburg 258 disconnect. | 1.225 | | | - - |
| 64-1995 | 1995-064 | 12/8/1995 | 11:13 | Vermont Yankee 1T and 81-1T breakers: Operated when unit tripped due to unstable reactor feed water valve con | 1.96 | | | - - |
| 65-1995 | 1995-065 | 12/13/1995 | 11:26 | Vermont Yankee 1T breaker: Operated due to air leak. | 4.516 | | | - - |
| 68-1987 | 1987-068 | 11/18/1987 | 01:27 | Ascutney K174 breaker: Operated due to a damaged insulator in PSNH's system. | .083 | | | - - |
| 70-1986 | 1986-070 | 8/5/1986 | 17:00 | Windsor H78 and H21, Hartford H83 breakers: Operated due to failed breaker bushings at CVPS Windsor sub. | 3.06 | | | - - |
| 70-1987 | 1987-070 | 12/30/1987 | 15:56 | Georgia K21 breaker: Operated due to loss of Sf6 gas. | 39.0 | | | - - |
| 70-1990 | 1990-070 | 12/4/1990 | 12:34 | Cold River H31 breaker: Operated due to a fault in CVPS' 46KV system. | 26.3 | | | - - |
| 71-1990 | 1990-071 | 12/10/1990 | 06:34 | Highgate VB60 breaker: Due to failure of one phase to open, the 48KV bus was taken out of service. | 102. | | | - - |
| 71-1994 | 1994-071 | 8/24/1994 | 17:03 | Queen City B43 breaker: Operated due to underground cable and L/A failure in BED's 13.8KV system. | .050 | | | - - |
| 72-1994 | 1994-072 | 9/5/1994 | 16:27 | Ascutney K149 breaker: Operated when 149 line tripped due to broken pole in NEPCO's system. | .016 | | | - - |
| 73-1990 | 1990-073 | 12/4/1990 | 04:28 | E. Fairfax X29 breaker: Operated due to hot line tie wire failure in VEC's 34.5KV system. | 7.51 | | | - - |
| 74-1986 | 1986-074 | 8/8/1986 | 15:11 | Windsor H78 and H21 breakers: Operated due to a defective CT at CVPS' Taftsville substation. | 1.21 | | | - - |
| 76-1993 | 1993-076 | 9/21/1993 | 14:51 | Vermont Yankee 379 and 381 breakers: Operated when an undetermined caused a trans. fault press. relay to oper | .916 | | | - - |
| 78-1993 | 1993-078 | 10/1/1993 | 06:48 | Sand Bar and Georgia K19, E. Fairfax X19 breakers: Operated due to a failed micromho module at Sand Bar. | 2.80 | | | - - |
| 79-1986 | 1986-079 | 8/12/1986 | 19:01 | W. Rutland and N. Rutland K37, Blissville H76 breakers: Operated due to a fault caused by a broken crossarm. | 20.4 | | | - - |

| sys_config | vt_load | weather | cause | sys_cond | fault_origin | | origin | perm_fault | velc_orig | prot_perf | inc_class | to_mgroper | published | preliminary |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 714.10 | N | EQ | N | | | S | TRUE | TRUE | I | RI | FALSE | TRUE | FALSE |
| | 728.00 | N | EQ | N | | | S | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | 753.20 | N | EQ | N | | | S | TRUE | TRUE | U | RI | TRUE | TRUE | FALSE |
| | 768.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 551.00 | N | EQ | N | | | S | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | 857.00 | N | EQ | N | | | S | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | 602.00 | N | EQ | N | | | S | TRUE | TRUE | U | RI | TRUE | TRUE | FALSE |
| | 718.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 773.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 802.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 679.00 | W | EQ | N | | | NL | TRUE | FALSE | I | RI | TRUE | TRUE | FALSE |
| | 840.00 | N | EQ | G | | | NL | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 609.70 | N | EQ | N | | | S | TRUE | TRUE | U | RI | TRUE | TRUE | FALSE |
| | 660.00 | I | EQ | N | | | S | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | .00 | S | EQ | N | | | D | TRUE | FALSE | U | RI | TRUE | TRUE | FALSE |
| | 607.30 | N | EQ | N | | | S | TRUE | TRUE | U | RI | TRUE | TRUE | FALSE |
| | 731.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | .00 | N | EQ | HCU | CV_EFAX-JOHN _X29 | LI_TR_LINE | D | TRUE | FALSE | U | RI | TRUE | TRUE | FALSE |
| | 467.10 | N | EQ | N | | | D | TRUE | FALSE | U | RI | TRUE | TRUE | FALSE |
| | 704.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 702.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 656.00 | N | EQ | N | | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| | 764.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 521.00 | S | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 701.00 | N | EQ | T | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 552.00 | N | EQ | TX | | | S | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | 359.20 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 526.00 | W | EQ | N | | | NL | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 627.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | .00 | S | EQ | N | | | NS | TRUE | FALSE | I | MI | TRUE | TRUE | FALSE |
| | 580.00 | N | EQ | N | | | T | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | .00 | E | EQ | VCU | | | D | TRUE | FALSE | U | RI | TRUE | TRUE | FALSE |
| | 674.00 | N | EQ | N | | | S | TRUE | TRUE | I | RI | TRUE | TRUE | FALSE |
| | 678.00 | N | EQ | D | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 675.00 | N | EQ | D | | | T | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | 655.00 | N | EQ | T | | | S | TRUE | TRUE | U | RI | TRUE | TRUE | FALSE |
| | 784.00 | N | EQ | T | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 532.00 | R | EQ | N | | | O | TRUE | FALSE | I | RI | TRUE | TRUE | FALSE |
| | 592.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 721.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 605.00 | N | EQ | N | | | S | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | 520.00 | E | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 443.00 | N | EQ | N | | | S | TRUE | TRUE | U | RI | TRUE | TRUE | FALSE |
| | 538.00 | S | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 513.00 | N | EQ | N | | | NS | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 623.00 | R | EQ | N | | | S | TRUE | TRUE | I | MI | TRUE | TRUE | FALSE |
| | 567.00 | N | EQ | N | | | L | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | 623.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 459.00 | N | EQ | N | | | L | TRUE | TRUE | C | QI | TRUE | TRUE | FALSE |
| | 759.00 | H | EQ | N | | | NL | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 680.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 848.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 711.00 | N | EQ | HTG | | | NL | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 416.00 | R | EQ | TG | | | NL | TRUE | FALSE | I | MI | TRUE | TRUE | FALSE |
| | 576.00 | N | EQ | T | | | S | TRUE | TRUE | I | MI | TRUE | TRUE | FALSE |
| | .00 | E | EQ | N | | | T | TRUE | TRUE | I | RI | TRUE | TRUE | FALSE |
| | 421.00 | H | EQ | N | | | S | TRUE | TRUE | I | MI | TRUE | TRUE | FALSE |
| | 755.00 | N | EQ | N | | | NL | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 864.00 | N | EQ | N | | | NS | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 756.00 | N | EQ | N | | | NS | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 429.00 | N | EQ | N | | | NL | TRUE | FALSE | U | MI | TRUE | TRUE | FALSE |
| | .00 | N | EQ | N | | | D | TRUE | FALSE | I | RI | TRUE | TRUE | FALSE |
| | 891.00 | N | EQ | N | | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| | 761.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 596.00 | N | EQ | N | | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| | 697.00 | N | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 579.00 | W | EQ | N | | | NL | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 525.00 | S | EQ | N | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | .00 | N | EQ | D | | | D | TRUE | FALSE | U | RI | TRUE | TRUE | FALSE |
| | 715.00 | N | EQ | TX | | | NS | TRUE | FALSE | I | MI | TRUE | TRUE | FALSE |
| | 669.00 | N | EQ | N | | | L | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | .00 | N | EQ | N | | | L | TRUE | TRUE | U | RI | TRUE | TRUE | FALSE |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 87-1993 | 1993-087 | 11/1/1993 | 13:27 | Converter N.B1 and S.B1 breakers: Operated when a current transformer failed at HQ's Rouville substation. | 9.51 | | | - - |
| | 1996-005 | 1/22/1996 | 11:16 | Highgate H60, H10, and H11 breakers: Operated due to a failed insulator on the 48KV bus. | 1.569 | | | - - |
| | 1996-010 | 3/26/1996 | 01:21 | Irasburg H16 breaker: Operated due to failed fuse holder in CU's 48KV system. | 13.317 | | | - - |
| | 1996-024 | 6/1/1996 | 15:26 | Ascutney H70 breaker and 700 C/S: Operated due to failed insulator. | 4.311 | | | - - |
| | 1996-029 | 6/12/1996 | | Converter S.B1 and N.B1 breakers: Operated during an electrical storm when the Bedford T1 transformer failed. | | | | - - |
| | 1996-036 | 6/26/1996 | 07:09 | Barre X06 breaker: Operated due to a fault in GMP's 34.5KV system. | 4.263 | | | - - |
| | 1996-052 | 8/15/1996 | 22:23 | Converter S.B1 and N.B1 breakers: Operated due to failed South transformer. | 140.45 | | | - - |
| | 1996-058 | 10/14/1996 | 13:36 | Chelsea H80 breaker: Operated due to an insulator failure in WEC's 46KV system. | 4.046 | | | - - |
| | 1996-061 | 11/18/1996 | 06:48 | Essex, Georgia, Converter, Granite, Middlebury voltages: Low voltages due to fault in GMP's 334.5KV system. | 4.117 | | | - - |
| | 1996-066 | 12/9/1996 | 03:59 | Barre X06 breaker: Operated due to pole damage. | .399 | | | - - |
| | 1997-003 | 2/17/1997 | 19:02 | N. Rutland-Cold River-Coolidge K32 line: Operated due to broken crossarm on structure 64. | 3.129 | | | - - |
| | 1997-020 | 5/5/1997 | 07:42 | Ascutney C7 breaker and 7A MOD: Operated due to unbalance. | 16.299 | | | - - |
| | 1997-021 | 5/8/1997 | 05:53 | Coolidge K31-35 and K35 breakers: Operated due to a failed capacitor in a GCX relay for the K35 line. | 3.121 | | | - - |
| | 1997-073 | 11/5/1997 | 15:22 | K19 & K22 & PV20 Lines: Operated due to failed conduc | 10.193 | SLG | DPH | 11/11/1997 |
| | 1998-001 | 1/1/1998 | 23:53 | Blissville H29 breaker: Operated due to blown transformer fuse at CVPS Dorset substation. | | Other | DPH | 1/2/1998 |
| | 1998-023 | 2/24/1998 | 19:59 | Converter N.B1 and S.B1 breakers: Operated on loss of HQ's 1425/1428 Line. | | | | - - |
| | 1998-005 | 2/11/1998 | 20:14 | Converter N.B1 and S.B1 breakers: Operated on loss of HQ's 1425/1428 lines. | | L-L ph 1-3 | DPH | 1/19/1998 |
| | 1998-034 | 5/11/1998 | 16:28 | N. Rutland H71 breaker and 710 C/S: Operated on transformer differential due to a failed insulator. | | 2LG ph 1-: | JRF | 6/15/1998 |
| | 1998-037 | 5/19/1998 | 18:45 | Queen City X69 breaker and 690 C/S: Operated on transformer differential due to GMP's 32Y5 problem. | | 3LG | DPH | 5/22/1998 |
| | 1998-072 | 7/1/1998 | 07:35 | Barre X63 breaker: Operated on transformer differential due to a failed 34.5kV Bus Insulator. | | SLG ph 3 | JRF | 7/7/1998 |
| | 1998-077 | 7/8/1998 | 15:13 | Florence B10 breaker: Operated due to a failed L/A in VMCO's 46KV system. | | SLG ph 2 | JRF | 7/14/1997 |
| | 1998-093 | 8/21/1998 | 07:16 | Converter N.B1 and S.B1 breakers: Opened by SCADA due to failure of a deluge pump to operate. | | | | - - |
| | 1998-117 | 10/21/1998 | 02:58 | Converter N.B1 and S.B1 breakers: Moisture in junction box shorted transformer fault pressure relay | | | | - - |
| | 1998-118 | 10/23/1998 | 23:53 | Converter N.B1 and S.B1 breakers: Operated due to a faulty micro-switch in the transformer oil pressure relay | | | | - - |
| | 1998-124 | 12/21/1998 | 23:25 | Georgia and Sand Bar K19, E. Fairfax X67 breakers and Georgia 800 C/S: Operated due to failed L/A at Georgia. | | SLG ph 2 | JRF | 12/22/1998 |
| | 1999-005 | 3/11/1999 | 13:52 | Coolidge Transformer Differential | | Other | JRF | 3/16/1999 |
| | 1999-023 | 6/30/1999 | 19:54 | k24 line - Barre-Berlin: Broken Cross Arm | | SLG ph 3 | JRF | 7/1/1999 |
| | 1999-075 | 10/11/1999 | 17:06 | New Haven H74: Operated Due to a Faulty GCX Relay Capacitor. | | Other | JRF | 10/18/1999 |
| | 1999-076 | 10/11/1999 | 20:59 | New Haven H74: Operated Due to a Faulty GCX Relay Capacitor #2. | | Other | JRF | 10/18/1999 |
| | 1999-078 | 10/15/1999 | 21:51 | Bennington H37: Failed 46 kV Lightning Arrestor. | | SLG ph 1 | JRF | 10/18/1999 |
| | 1999-084 | 11/10/1999 | 17:28 | Coolidge Transformer Differential: Failed Transformer Tertiary Lightning Arrestor. | | 2LG ph 1-: | JRF | 11/11/1999 |
| | 2000-020 | 5/23/2000 | 00:58 | K22 Line: "B" phase compression T connector failure at structure in substation. | | SLG ph 2 | DEB | 7/24/2002 |
| | 2001-062 | 9/1/2001 | 09:46 | East Fairfax Transformer Differential: 115/34.5 KV Transformer Failed. | | Other | DEB | 9/13/2001 |
| | 2002-017 | 5/13/2002 | 19:02 | K32 Line (COOL-COLD-NRUT) Operated to lockout, blown L/A at COOL. | | 2LG ph 1-: | DEB | 5/21/2002 |
| | 2002-047 | 8/5/2002 | 11:45 | New Haven & Middlebury K63 breakers both operated once automatically | | SLG ph 1 | DEB | 8/6/2002 |
| | 2002-075 | 12/11/2002 | 11:23 | ITIC Violation: CVPS Mendon B-86 operated and locked out. | | 2LG ph 1-: | DEB | 1/2/2003 |
| | 2003-004 | 3/29/2003 | 21:44 | Vermont Yankee 379, K1, 381, 79-40 and Scobie 379 line terminal breakers opened due to 379 stuck beaker. | | Other | JRF | 3/29/1903 |
| | 2003-007 | 4/11/2003 | 10:06 | Sand Bar K20: Plattsburg Phase Shifting Transformer Failure | | 3LG | JRF | 6/3/1903 |
| | 2003-009 | 5/25/2003 | 18:06 | Highgate Converter N.B1: Temporary Block Due to H.Q's 1428 Line Operation. | | 3LG | JRF | 12/29/2003 |
| | 2003-012 | 6/11/2003 | 00:30 | Barre X04: Operated to lockout due to a failed line pot within GMP's system. | | 2LG ph 2-: | JRF | 6/25/1903 |
| | 2003-018 | 7/17/2003 | 06:34 | Ascutney H70, H19, H20, and 700: Opened automatically on transformer differential. | | | | - - |
| | 2003-032 | 9/7/2003 | 06:38 | Barre K24: Open and locked out. | | | | - - |
| | 2003-037 | 10/4/2003 | 12:23 | Essex X10, X11 and 100: Opened automatically on transformer differential. | | | | - - |
| | 2003-051 | 12/9/2003 | 09:31 | Chelsea H81: Opened and closed automatically due to bus fault at CVPS Bethel sub. | | | | - - |
| | 2004-001 | 1/16/2004 | 02:14 | Highgate Converter Tripped: HQ 1429 Line Tripped | | 3LG | JRF | 1/19/1904 |
| | 2004-005 | 2/27/2004 | 09:16 | Essex X20 & X21: Breakers Operated when the Pilot Scheme was turned off at GMP. | | Equip. Fail | RAB | 3/15/1904 |
| | 2004-010 | 3/12/2004 | 23:46 | Highgate H10: Permanent fault in T1 Transformer at Rock Tenn Plant. | | 2LG ph 1-: | rcs | 3/23/2004 |
| | 2004-012 | 3/23/2004 | 14:15 | Middlesex X65: Operated to lockout due to failed lighting arrestor at GMP sub. | | Gnd Unkn | rcs | 4/6/2004 |
| | 2004-013 | 4/2/2004 | 16:47 | Highgate C220 and C230: Operated to lockout due to broken crossarm. | | Gnd Unkn | rcs | 4/6/2004 |
| | 2004-015 | 4/7/2004 | 13:08 | Essex/Statcom: Bus #2 differential/K98 breaker failure. | | SLG ph 2 | rcs | 4/19/2004 |
| | 2004-024 | 5/15/2004 | 09:28 | North Rutland H71: Operated due to Insulator failed on CVPS's B4 circuit. | | SLG ph 1 | rcs | 5/20/2004 |
| | 2004-047 | 6/18/2004 | 06:41 | Vermont Yankee 1T and 81-1T breakers: Operated when unit tripped due to a main transfomer fire. | | L-L ph 2-3 | rcs | 6/29/2004 |
| | 2004-049 | 6/22/2004 | 17:07 | Florence B10 Breaker: Operated to lockout due to broken crossarm. | | L-L ph 2-3 | rcs | 6/28/2004 |
| | 2004-077 | 7/22/2004 | 13:11 | Ascutney K174: Operated to lockout due to a broken crossarm. | | SLG ph 2 | rcs / jjc | 7/29/2004 |
| | 2004-079 | 8/2/2004 | 21:45 | Florence B12 Breaker: Operated to lockout due to blown L/A on 727 disconnect. | | SLG ph 2 | JJC | 8/3/2004 |
| | 2004-111 | 10/18/2004 | 20:58 | Highgate Converter Tripped: HQ 120-2 breaker Failure at St. Cesaire. | | Equip. Fail | JJC | 10/28/2004 |
| | 2005-003 | 1/13/2004 | 23:20 | Highgate H11 C210 and C220 all opened for 48 KV bus differential. | | Equip. Fail | JJC | 2/8/2005 |
| | 2005-008 | 2/12/2005 | 11:06 | ITIC Violation: Bellows Falls #3 Transformer Differential Operated Due to Bad B Phase Tap | | SLG ph 3 | JJC | 2/17/2005 |
| | 2005-009 | 2/16/2005 | 11:36 | Cold River H31 breaker: Operated due to a fault in CVPS 46KV system. | | Other | JJC/JRF | 2/16/2005 |
| | 2005-014 | 4/22/2005 | 15:30 | Cold River H32 Breaker: Operated due to a failed line VT on the B-12 circuit at CVPS Lalor Avenue | | 3LG | JJC | 4/26/2005 |
| | 2005-015 | 4/23/2005 | 02:56 | Berlin X90 Breaker: Operated due to a failed fuse disconnect insulator at GMP Berlin | | 3LG | JJC | 4/26/2005 |
| | 2005-017 | 4/23/2005 | 19:49 | Hartford H83: Operated due to internal fault on CVPS Thetford transformer. | | L-L ph 1-2 | JJC/JRF | - - |
| | 2005-018 | 4/23/2005 | 16:16 | Vermont Yankee 379 and 79-40 breakers tripped due to a broken 345 KV crossarm at PSNH structure 481. | | SLG ph 1 | JJC | 4/28/2005 |
| | 2005-019 | 4/30/2005 | 06:13 | St. Albans Transformer Differential: X61 Source POT Failed. | | 3LG | JJC/JRF | 4/3/2005 |
| | 2005-025 | 5/19/2005 | 05:03 | Highgate Converter: Main Breakers Tripped, S.Z6.B breaker Failure. | | Equip. Fail | JJC | 6/6/2005 |

Docket No. 7032
George E. Smith, Witness
Exhibit DPS-GES-13

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 773.00 | N | EQ | N | | | NS | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 864.0 | | EQ | | | | | TRUE | TRUE | | RI | TRUE | TRUE | FALSE |
| | 480.0 | | EQ | | | | | TRUE | FALSE | | RI | TRUE | TRUE | FALSE |
| | 584.0 | | EQ | | | | | TRUE | TRUE | | MI | TRUE | TRUE | FALSE |
| | 766.0 | | EQ | | | | | TRUE | FALSE | | MI | TRUE | TRUE | FALSE |
| | 676.0 | | EQ | | | | | TRUE | FALSE | | RI | TRUE | TRUE | FALSE |
| | 635. | | EQ | | | | | TRUE | TRUE | | RI | TRUE | TRUE | FALSE |
| | 704.0 | | EQ | | | | | TRUE | FALSE | | RI | TRUE | TRUE | FALSE |
| | 686.0 | | EQ | | | | | TRUE | FALSE | | RI | TRUE | TRUE | FALSE |
| | 573.0 | | EQ | | | | | TRUE | FALSE | | MI | TRUE | TRUE | FALSE |
| | 850.0 | | EQ | | | | | TRUE | TRUE | | QI | TRUE | TRUE | FALSE |
| | 700.0 | | EQ | | | | | TRUE | TRUE | | MI | TRUE | TRUE | FALSE |
| | 650.0 | | EQ | | | | | TRUE | TRUE | | MI | TRUE | TRUE | FALSE |
| | 706.0 | I | EQ | | | | L | TRUE | TRUE | | QI | TRUE | TRUE | FALSE |
| Normal, load 675MW, Converter 217MW, McNeil off line | 675 | N | EQ | | | | D | TRUE | FALSE | C | QI | TRUE | TRUE | FALSE |
| | 800 MW | S | EQ | | | | NL | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| Normal w/o Highgate Converter, load 502 MW, McNeil off line | 845 | N | EQ | | | | NL | TRUE | FALSE | I | MI | TRUE | TRUE | FALSE |
| McNeil 47 MW; Converter 129 MW; North Rutland B2 Open; Lalor Avenue B6 Open | 685 | N | EQ | | | | S | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| Nominal, Converter 130MW, McNeil 45MW | 655 | N | EQ | | | | T | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| Normal: Converter 200 MW; McNeil 31 MW | 747 | R | EQ | | | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| Nominal System; Converter 203MW; McNeil 50MW | 747 | N | EQ | | | | S | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | 697 | N | EQ | | | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| | 475 | N | EQ | | | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| | 581 | N | EQ | | | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| Converter 210MW; McNeil 15MW; Nominal System Configuration | 560 | R | EQ | Normal | VE_GEOR-SAND _K19 | LI_TR_LINE | S | TRUE | TRUE | C | QI | TRUE | TRUE | FALSE |
| Converter 206 MW; McNeil OOS; Nominal System | 821 MW | N | EQ | | VE_COOL | | T | TRUE | TRUE | I | MI | TRUE | TRUE | FALSE |
| Nominal System; Load 754MW; McNeil 50MW; Converter 193 MW | 754 | N | EQ | normal | VE_BARR-BERL _K24 | LI_TR_LINE | L | TRUE | TRUE | C | QI | TRUE | TRUE | FALSE |
| Contingency System; Vergennes 3322 Closed; McNeil OOS for Maintenance | 720 | N | EQ | | VE_NHVN | | S | TRUE | TRUE | I | RI | TRUE | TRUE | FALSE |
| New Haven 499 Open; New Haven 7PF Open | 700 | N | EQ | | VE_NHVN | | S | TRUE | TRUE | I | RI | TRUE | TRUE | FALSE |
| Nominal System; Y25 Closed; Converter MW; McNeil MW | 634 | N | EQ | | VE_BENN | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| Coolidge KT1 & KT1-32 Open | 826 | R | EQ | | VE_COOL | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| See Op's description; Sys Load: 530MW; McNeil: 50MW; Conv: 67MW | 530 | N | EQ | | | | L | TRUE | TRUE | I | QI | TRUE | TRUE | FALSE |
| Sys Load: 703MW; McNeil: 37MW; Conv: 200MW | 703 | N | EQ | | | | S | TRUE | TRUE | C | MI | TRUE | TRUE | FALSE |
| Sys Load: 763MW; McNeil: 51Mw; Conv: 213MW | 763 | R | EQ | | | | L | TRUE | TRUE | C | QI | TRUE | TRUE | FALSE |
| See Op's description; Sys Load: 963MW; McNeil: 50MW; Conv: 213MW | 963 | N | EQ | abnormal | | | L | TRUE | TRUE | I | QI | TRUE | TRUE | FALSE |
| See Op's description; Sys Load: 912MW | 912 | N | EQ | | | | D | TRUE | FALSE | C | QI | TRUE | TRUE | FALSE |
| Nominal | 600 | N | EQ | Normal | | | S | TRUE | TRUE | | MI | TRUE | TRUE | FALSE |
| Nominal System, 770 MW, McNeil 15MW, Converter 202MW | 770 | N | EQ | Normal | | | NT | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| Plattsburgh PAR Bypassed, OMS in service, K186 Line OOS | 618 | R | EQ | | | | NL | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| Plattsburg PAR Bypassed, OMS In Service, McNeil OOS, Load 527MW | 527 | N | EQ | | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 699 | N | EQ | | | | S | TRUE | TRUE | C | RI | TRUE | TRUE | FALSE |
| | 533 | N | EQ | | | | S | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 720 | R | EQ | Normal | | | S | TRUE | TRUE | C | QI | TRUE | TRUE | FALSE |
| | 895 | N | EQ | | | | NS | TRUE | FALSE | C | QI | TRUE | TRUE | FALSE |
| Nominal System, Plattsburg PAR OOS, OMS Bypassed | 750 | S | EQ | | | | NS | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| | 871 | N | EQ | | | | D | TRUE | FALSE | I | MI | TRUE | TRUE | FALSE |
| Plattsburgh PAR bypassed, Sandbar OMS bypassed. | 642 | N | EQ | | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 809 | N | EQ | | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| Plattsburgh PAR bypassed and Sandbar OMS Bypassed | 740 | N | EQ | | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| Plattsburgh PAR bypassed, Sandbar OMS bypassed, 340 line out of service | 755 | N | EQ | | | | S | TRUE | TRUE | C | QI | TRUE | TRUE | FALSE |
| Plattsburgh PAR OOS, Sandbar OMS inserted, Williston K23 breaker OOS for insp'n | 730 | N | EQ | | | | D | TRUE | FALSE | I | QI | TRUE | TRUE | FALSE |
| VY at 516 MW when the fault occurred | 708 | N | EQ | | | | NT | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| Vermont Yankee OOS | 807 | R | EQ | | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| | 961 | N | EQ | | | | NL | TRUE | FALSE | C | QI | TRUE | TRUE | FALSE |
| Normal | 839 | N | EQ | | | | D | TRUE | FALSE | C | RI | TRUE | TRUE | FALSE |
| Normal | 675 | N | EQ | | | | NS | TRUE | FALSE | C | MI | TRUE | TRUE | FALSE |
| Normal | 625 | W | EQ | Normal | | | D | TRUE | FALSE | | QI | TRUE | FALSE | FALSE |
| Normal | 814 | N | EQ | Normal | | | NT | TRUE | FALSE | C | QI | TRUE | FALSE | FALSE |
| Cold River H31 breaker reclosing blocked for CVPS tree crew. | 822 | N | EQ | Normal | | | NL | TRUE | FALSE | A | QI | TRUE | FALSE | FALSE |
| Cold River H32 auto blocked, CV Lalor B-3 & B-12 Open | 685 | N | EQ | Normal | | | D | TRUE | FALSE | C | QI | TRUE | FALSE | FALSE |
| Normal | 477 | R | EQ | Normal | | | D | TRUE | FALSE | C | QI | TRUE | FALSE | FALSE |
| Normal | 705 | R | EQ | Normal | | | D | TRUE | FALSE | C | QI | TRUE | FALSE | FALSE |
| Normal | 646 | N | EQ | Normal | | | NL | TRUE | FALSE | C | RI | TRUE | FALSE | FALSE |
| Normal | 530 | N | EQ | | | | S | TRUE | TRUE | C | QI | TRUE | FALSE | FALSE |
| Converter Shutdown in progress | 549 | N | EQ | Normal | | | S | TRUE | TRUE | C | MI | TRUE | FALSE | FALSE |

21. Refer to Ryan Johnson's Rebuttal Testimony at p. 3, Q&A5. Please provide the rationale, assumptions, and all supporting structural calculations supporting the recommendation to use steel poles supported by concrete foundations.

The use of steel poles on concrete foundations is recommended over the use of direct embedded poles because:

- A properly designed steel pole and concrete foundation are more predictable than a direct embedded pole because it uses materials that are completely engineered. A wood pole can be unpredictable because mother nature created it and the potential defects that may be inside the pole are not obvious. Wood poles are specified to meet certain minimums, but they can have defects that create weak spots. Varying soil conditions can also affect the stability of the pole when direct embedded. Placing a steel pole on a properly engineered foundation creates a more stable environment for the pole.
- Discussions with other utilities have shown that steel structures utilizing concrete foundations are preferred over direct embedding due to longevity and reliability especially for critical circuits. Getting the steel pole out of direct contact with the soil has shown to give the pole a longer life span.
- VELCO has, since the inception of this project, reduced the level of desired reliability it wants from this project from what was originally proposed. Originally VELCO desired an H-frame 115 kV structure in a right-of-way with the 34.5 kV line 50 feet from the 115 kV structure. However, due to the close proximity of homes within the corridor, VELCO designed the proposed configuration. If VELCO is asked to construct single pole, double circuit lines then it feels steel poles with concrete foundations should be used to minimize the exposure for loss of one of these poles and in turn to maximize the electrical reliability to the area.

Response provided by Ryan Johnson.

27. One of the pole height reduction measures suggested by Department witness Smith involves reducing the pole height measured from the top conductor to the static wire which decreases the cone angle from nominally 60 degrees to 45 degrees. Does VELCO believe that this particular measure will impact vegetation management?

No, but this would reduce the shield angle to what is considered the bare minimum for transmission line design on a transmission line that is critical to the Lamoille County area reliability.

Response provided by Ryan Johnson.

36. Refer to Ryan Johnson's Rebuttal Testimony at p. 4, Q&A10. Does VELCO agree that Department witness Smith's "shield angle" calculation of approximately 60 degrees, using his definition whereby the angle is measured from a horizontal plane containing the topmost conductor up to the shield wire at the structure, corresponds to VELCO witness Johnson's shield angle of 34 degrees (approximately 30 degrees) measured from a vertical plane containing the shield wire to the top conductor?

Yes, but using the horizontal plane to measure the shield angle conflicts with the industry standard method of using the vertical plane.

Response provided by Ryan Johnson.

38. Please provide all analyses quantifying and supporting VELCO's concerns with the reduction in reliability that would result from employing Department witness Smith's proposed pole height reduction by lowering the shield wire. Include the probable increased incidence of both momentary faults and permanent faults (those resulting from lightning induced equipment failure).

VELCO has not performed such analysis.

Response provided by Ryan Johnson.

24. Refer to Ryan Johnson's Rebuttal Testimony at pp. 3-4, Q&A7. Does VELCO believe that lowering the pole height by using shorter spans and thereby reducing the sag cause the conductor to be lower at mid span than for the proposed configuration?

No, but this does result in a higher cost line both initially and for future maintenance. The point that was being made in Q&A7 of the rebuttal testimony was that as conductors on poles with reduced pole heights/shorter spans get further from mid-span and closer to the poles, they are closer to the ground than conductors on optimized pole heights/spans. The fact that overall the conductors on reduced pole height/shorter spans are closer to the ground, vegetation management becomes more of a concern.

Response provided by Ryan Johnson.

25. Please describe why lowering the height of the pole increases the concern with vegetation management.

Any reduction in conductor height will have a direct effect on the vegetation that can be tolerated inside the right-of-way.

Response provided by Jeff Wright.